Counterpoint: Exploring Mixed-Scale Gesture Interaction for AR Applications

Abstract
This paper presents ongoing work on a design exploration that interleaves microgestures with other types of gestures from the greater lexicon of gestures for computer interaction. We describe three prototype applications that show various facets of this multi-dimensional design space. These applications portray various tasks on a Hololens Augmented Reality display, using different combinations of wearable sensors. Future work toward expanding the design space and exploration is discussed, along with plans toward evaluation of multi-scale gesture design.

Author Keywords
Gesture interaction; wearable computing; Augmented reality

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Introduction
Computer interfaces have often made successful use of gestures to allow rich and intuitive interaction. The strategy of mimicking our everyday interactions with real-world objects allows us to map high-level mental models onto appropriate sequences of physical actions [3]. Interaction designers have often sought to make...
such interactions analogous to everyday interactions with real-world objects. With the mouse, for example, users apply a combination of motions and clicking gestures to select or move data objects on a virtual desktop. More recently, touch screens allow tapping and swiping gestures, which allow data objects and interface components to be manipulated using fingers, without an intermediary device. In next-generation Augmented Reality (AR) interfaces, gesture interaction will more closely resemble interactions with real-world objects, since users can point at [2] or grasp [16] virtual objects overlaid directly on the environment.

While such “natural” interactions can be highly appealing for AR applications, “in-air” gestures are currently prone to several disadvantages, such as fatigue, imprecision, and social awkwardness. Fatigue is caused by interactions that require the arms to be extended from the body for a prolonged period [9]. Precise interaction is known to be difficult without the aid of a haptic surface, limiting practical applications. Social awkwardness may arise in some social contexts, when gestures attract attention from observers who do not have a complete picture of what a user is doing [1].

To address these concerns, researchers have explored microgestures, minute gestures performed by the hands or fingers [22]. Microgestures rely on sophisticated sensing methods that are capable of detecting fine-scale hand motions. Such methods include computer vision techniques for articulated hand-tracking [18] and sub-millimeter radar [12].

**Contribution**
Microgestures have primarily been explored on their own, without considering the user’s long-term goals. In contrast, this work builds toward a design space for applying microgestures within the greater gestural lexicon [6]. This goal of this design space and ensuing exploration, which we term *Counterpoint*, is to elicit broad thinking about complex sequences of tasks, where interplay between complementary gestures is leveraged to achieve a sequence of user goals.

Our ongoing work will produce the following set of contributions:

- A complete design space for gesture interaction based on an exhaustive literature review.
- Introduction of the dimension of *scale* for mixed-scale gesture interaction
- A design space exploration that includes several example implementations of mixed-scale gestures
- The first evaluation of whether mixed-scale gesture interaction can mitigate issues of in-air gestures such as precision, fatigue and social awkwardness.

These contributions will help AR interaction designers support complex tasks and will hopefully encourage further exploration of the Counterpoint design space and mixed-scale interactions. This paper builds on our prior work that introduced the concept of mixed-scale gestures and the applications presented below [7]. Here we expand on our planned contributions, solidify the definition of our design space, discuss how our applications demonstrate the design dimensions, and outline our planned evaluation.

**Counterpoint Design Space**
The central idea of the Counterpoint design space is to facilitate the design of interactions leverage the advantages of different gesture types. For instance,
large gestures such as pointing and 6-dof manipulation can be fast and convenient, but excessive reliance on such gestures can lead to arm fatigue or social awkwardness. Meanwhile, small finger movements can provide precision and subtlety, but may lack the expressivity of larger gestures.

While our main focus is on mixed-scale interaction, which integrates of microgestures and macrogestures into more complex interaction sequences, we need to view such designs within the context of a complete design space for gesture interaction. Therefore, one of the goals of this work is to provide an extensive gesture design space by consolidating the many previous taxonomies and design spaces for gesture interaction that have been introduced in prior work.

The course towards current thinking on gestural interaction design spans multiple research disciplines over several decades. Early taxonomies for gestures were introduced in the fields of linguistics and psychology, and were aimed at classifying different types and purposes of hand gesticulations commonly made during speech [4,5,10]. Later taxonomies introduced gestures made in conjunction with speech as a natural method of interacting with computers [17,20]. More recent design spaces have introduced new elements specifically geared toward computer interaction. Some of these are aimed at specific contexts for gesture interaction, such as multitouch input for tabletops [21], motion gestures for mobile phones [19], or wearable augmented reality [15].

In this work, we aim our design space toward designers of applications for wearable AR. In particular, we explore “in-air” gestures, which allow users to move freely and interact naturally in the environment where an application is situated, by eliminating the need for handheld devices. Moreover, we are interested in moving toward productive AR applications, which may include entertainment, but also situated analytics of environmental sensor data, interaction with networks of smart objects, and computer aided design (CAD). Such applications are likely to require complex sequences of nuanced commands.

**Design Dimensions**

A design space for gesture interaction is presented in Figure 1. These dimensions are compiled from a literature review of prior taxonomies and design spaces for gesture interaction, and is refined for our contextual focus on in-air gestures for wearable AR. Whereas this space encompasses many dimensions drawn from various sources, we introduce scale as the central dimension of this exploration. Microgesture and macrogestures have previously been explored independently, however to our knowledge, scale has not been included as a dimension in any previous gesture taxonomy or design space, and mixed-scale gestures have not been explicitly studied.

The scope of this paper does not allow us to include a detailed description of each dimension, however we are continuing to compile and refine a complete design space which will be fully presented in future work.

**Design Space Exploration**

To demonstrate the concept of mixed-scale interaction, we are implementing a series of applications within the Counterpoint design space. These interactions are not proposed as ideal workflows for the given scenarios, but are chosen to explore various facets of the design space.
space and to inspire further exploration of gesture combinations.

These implementations rely on various combinations of wearable sensors, as will likely become commonplace as wearable systems proliferate. Macro-scale hand gestures are tracked using a Leap Motion device mounted on a HoloLens [14] wearable AR display (Figure 2). For microgesture sensing, we use body-mounted Leap Motion [11] and Google Soli [8] sensors (Figure 3), which currently provide the best capabilities for detecting small hand movements. Below we describe three implementations, and explain how each leverages various dimensions of the Counterpoint design space (with keywords in italics). We continue to develop further examples as our work progresses.

Demo #1: Precise Object Manipulation
The first application (Figure 4a) demonstrates precise object manipulation, an operation that may be required for applications such as CAD or visual analytics. For demonstration purposes, we use a docking task. A head-worn Leap sensor (Figure 2) can detect grasping and manipulation gestures, which can be used to place an object near the specified position. The user can then fine tune the object’s pose with the arm down in a relaxed posture [13]. A belt-worn sensor configuration (Figure 3) detects small movements of the thumb when placed against the sides or tips of the fingers. Six virtual sliders can be used individually to provide precise control over the object’s three axes of translation and rotation (Figure 4).

This docking task solution provides an example of unimanual, sequential interaction. The initial 6-dof object manipulation is an example of compound chunking, the grouping of parameter manipulations to fit high-level mental models [3]. The subsequent fine-tuning is supported by isolating each axis into simple components. In this case, pose information provided by the Leap sensor determines which component to activate, while the Soli provides fine-scale microgesture sensing to control 1D sliders, which are mapped to either discrete or continuous input.

Demo #2: Virtual Puppetry
The second application explores virtual puppetry (Figure 5), which is inspired by marionette operators who commonly combine multiple gesture scales. As in the first application, a head-mounted Leap device senses large gestures made by the arm and hand, which in this case control the position and direction of a virtual puppet (Figure 5b). A Soli sensor, mounted under the wrist meanwhile senses subtle motions of the fingers below the occluded hand, which control various animations. For instance, while a pointed index finger indicates the puppet’s running direction, the middle finger controls the speed of a running animation, which transitions to walking as the middle finger is extended. Conversely, lowering the index finger controls the speed and swinging direction of the puppet’s toy sword.

This example demonstrates unimanual control of simultaneous modes. The index finger pose provides a metaphoric gesture to indicate the puppet’s running direction while continuous microgestures control animation speeds. In this implementation, the limit of the arm’s reach restricts the puppet to personal space.

Demo #3: In-Situ Video Editor
The third example explores a tool for in-situ cropping of short videos that might be taken with a head-worn AR
display’s camera. While one hand points to a position on a virtual scrubbing slider (Figure 6a), the second hand produces a “snipping” gesture, detected by a belt-worn Soli sensor (Figure 6b), to apply a cropping operation at the desired point.

This example demonstrates bimanual interaction; the head-mounted sensor detects large-scale deictic gestures on the video slider, while a pre-trained mimetic gesture triggers the cropping action. Other types of motion gestures could potentially be trained to provide a vocabulary of editing operations.

Evaluation of Mixed-Scale Gestures
Our next steps include the design and execution of a user study to evaluate the benefits of multi-scale gesture design. We plan to implement a simple version of the demonstrated docking task, to compare multi-scale gesture interaction against individual use of microgestures and macrogestures. As metrics, we will measure task precision, user fatigue, and perceived social acceptability. Whereas prior studies of fatigue have used subjective ratings or macro-scale sensing [9], we will measure fatigue using electromyography to capture fatigue at multiple scales.

Conclusion
In summary, this paper outlines our ongoing progress in the development of the Counterpoint design space, aimed at facilitating design of multi-scale gesture interactions. We present three initial applications that explore this design space and demonstrate the interaction possibilities of multi-scale gesture design for wearable AR. Future work will continue these developments and introduce the first user study to evaluate multi-scale gestures by measuring fatigue.

References


